

The invention relates to an apparatus for the transmission and/or the  
5 reception of data, and more particularly to an apparatus of this kind which  
comprises protection means.

15 **Explanation about link protection:**

After repair of the failed working link, either this repaired link returns to the original state, or this previously working link becomes a protecting link .

The protection ratio of the working links is variable. A protection ratio of 1:N means that 1 protecting link is provided for N working links. This ratio may be zero. In that case, no automatic protection mean is provided and the traffic through the failed working link is rerouted over other links routed to the same destination.

At each end of a link is associated a device for transmission and reception of data which is named a "terminating board". In order to protect the transmission system from failures of such boards additional terminating boards  
5 are generally provided at each end. The additional board(s), named spare board(s), replace(s) an active board when the latter fails.

10           The invention starts from the recognition that in the known equipment,  
the protection ratio of the working links depends on the protection ratio of the  
terminating boards. The invention overcomes this drawback and provides an  
apparatus for transmission and/or reception of digital data which may be  
designed with a greater degree of freedom, the protection ratios of the links and  
15 of the terminating boards being selectable independently from each other.

20        - a plurality of inputs and a plurality of corresponding outputs for the  
respective coupling to the incoming part and outgoing part of a plurality of links,  
wherein, to each input and to each output is associated a respective switching  
device,

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35 be interpreted as being limitative to the means listed thereafter. Thus the scope

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Similarly, it is to be noticed that the term “coupled”, also used within this document, should not be interpreted as being limitative to direct connections only.

5 Thus the scope of the expression “ a device A coupled to a device B” should not be limited to devices or systems wherein an output of device A is directly connected to an input of device B. It means that there exists a link between an output of A and an input of B, possibly via other devices between A and B.

With the switching device or devices of the invention, the protection ratios  
10 of the links and of the terminating boards are selectable independently from each  
other. In other words, link protection and board protection are orthogonal.

In the preferred embodiment, each switching device comprises a 2 x 2 switch or a similar switch, such as a 4 x 4 switch.

15 The 2x2 switches have each four terminals, wherein one of which is connected to an input or output, another terminal is connected to the input or output of an active terminating board and a third terminal is connected to the corresponding input or output of a spare terminating board.

As it has been observed that the design of known equipment or exchanges are such that some failures may not be detected, such as failures in the connections provided for the replacement of a working link by a protecting link or a connection for replacing an active terminating board by a spare terminating board, in a particular embodiment, the invention takes advantage of the switching devices, more particularly the 2x2 switches or similar to test the continuity of the connection between the links and the spare terminating boards, a test function being incorporated in such spare terminating boards.

In known equipment, either the control and switching of the failing links, or the control and switching of the failing boards are not centralized. This causes interchanging messages over different boards to control and perform the switching function. This exchange of messages entails a waste of time and the risk of losing data.

In order to overcome this drawback, in an embodiment, the protecting controls are centralized. Therefore, with this architecture, it is possible to minimize the time required for replacing automatically a failed terminating board by a spare terminating board and to minimize the time for replacing a failed working link by a protecting link. Consequently, the risk of losing data is minimized.

Preferably, in order to allow a replacement of the switching devices, such as the 2 X 2 switches, without interrupting the traffic and to simplify the manufacture and the use of such exchanges, the 2x2 switches are installed on a panel, called an applique, together with the corresponding control means for these switches.

For the same reason of simplicity of manufacture and use, the wires or fibers connecting the switching devices to the terminating board are preferably installed on a single panel which will be called here a back panel.

The terminating boards are also preferably installed on a common terminating panel.

In an embodiment, the protection of the terminating boards is performed from the applique panel and controlled from the terminating panel and the control operation for protecting the links is performed on the terminating panel. It is recalled here that the protection of a terminating board comprises the step of replacing the defective terminating board by a spare terminating board through an appropriate modification of the connection(s) between the switching devices and the terminating boards. By protection of the links, it is meant here that the detection of failures of a link is performed on the corresponding terminating board as well as the generation of control signals requesting the replacement of a working link by a protection link, such as the transmission of bytes  $K_1$  and  $K_2$  according to the ITU standard n° G.783 , after which steps the final coupling to the spare link is performed.

It is recalled here that, before a repaired board can be put in service again, usually it has to be tested. This test is conventionally performed by an internal loop on the board, but the connections to the external links are not tested.

The architecture of this invention provides that a ( repaired ) board can be tested, including the external links, independent of other ( test ) boards.

Other features and advantages of the invention will appear with the description of the herein-appended drawings in which :

- figure 1 represents schematically an exchange according to the invention with one working link, one protecting link, one terminating board and one spare board,
- figure 2 represents the same exchange as the one shown on figure 1 but in a different operating mode, and

The example of the invention which will be described with the drawings is a switching or routing device for transmission and reception of digital data such as an equipment for transmission and reception of data according to the Internet 5 Protocol (IP). However, it can also be used in ATM, PSTN, or STM networks.

15           Link W is hereafter called a "working" link, which, in a 1:1 protection configuration is always coupled to a "protection" link. In a later paragraph, the more general case of 1:n protection will be dealt with, with which it is meant that one protection link is provided for n working links.

To the working link W is associated a protecting link P comprising also a forward link coupled to another input 10<sub>3</sub> and a return link coupled to another output 10<sub>4</sub>. Both links may again be integrated into one conductor. This protecting link P replaces the working link W in case of failure of the latter.

According to the preferred embodiment of the invention, to each line end is associated a 2x2 switch and all the 2x2 switches are coupled and controlled in such a way that, in case of failure of a terminating board 12<sub>1</sub>, this active  
35 terminating board 12<sub>1</sub> is replaced by a spare terminating board 12<sub>2</sub>. Preferably, the 2x2 switches are used for testing, from the spare terminating board, the

reserved link(s) which is (are) used only in case of replacement of the active terminating board by the spare terminating board 12<sub>2</sub>.

More precisely, as shown on figure 1, to the input end 10<sub>1</sub> of link W is associated a 2x2 optical switch 14<sub>1</sub> comprising four terminals 16<sub>1</sub>, 16<sub>2</sub>, 16<sub>3</sub> and 16<sub>4</sub>, and second control means (26<sub>1</sub> and 41) for modifying the connection between these terminals. The switch 14<sub>1</sub> has two operating positions: in the first operating position, the terminal 16<sub>1</sub> is coupled to the terminal 16<sub>3</sub>, and the terminal 16<sub>2</sub> is coupled to the terminal 16<sub>4</sub>, as shown in thick full and broken lines respectively, and in the second operating position, the terminal 16<sub>1</sub> is coupled to the terminal 16<sub>4</sub>, and terminal 16<sub>2</sub> is coupled to terminal 16<sub>3</sub>, as is shown by the thin broken lines.

In the operating mode represented on figure 1 with thick lines, the connections 16<sub>1</sub>–16<sub>3</sub> and 16<sub>2</sub>–16<sub>4</sub> are used. In the operating mode represented on figure 2, the connections which are used are 16<sub>1</sub>–16<sub>4</sub> and 16<sub>2</sub>–16<sub>3</sub>.

In a similar way, a 2x2 switch 14<sub>2</sub> is associated to the output end 10<sub>2</sub> of link W, and two respective 2x2 switches 14<sub>3</sub> and 14<sub>4</sub> are respectively associated to input 10<sub>3</sub> and output 10<sub>4</sub> coupled to link P.

In Fig. 1, the terminal 16<sub>3</sub> of switch 14<sub>1</sub> is coupled to an input 18<sub>1</sub> of a detection circuit 20<sub>1</sub> of the active terminating board 12<sub>1</sub>. One output 22<sub>1</sub> of circuit 20<sub>1</sub> is coupled to the terminal 16'<sub>3</sub> of switch 14<sub>2</sub>. The function of circuit 20<sub>1</sub> is, on one hand, to detect signal failures (SF) and signal degradation (SD) of the data received from input 10<sub>1</sub> and, on the other hand, to transmit the received data to a data transmission / reception circuit 24<sub>1</sub>. When a signal failure or a signal degradation is detected by circuit 20<sub>1</sub>, this SF or SD information is transmitted to a controller 26<sub>1</sub> on the terminating board 12<sub>1</sub> and this controller 26<sub>1</sub> provides a control signal to a request circuit 28<sub>1</sub> of the same board 12<sub>1</sub>. This circuit 28<sub>1</sub> generates K<sub>1</sub> and K<sub>2</sub> requests which are the standardized bytes used for requesting the replacement of a working link by a protection link. These K<sub>1</sub> and K<sub>2</sub> bytes are transmitted through the protection link P as indicated by the thick black lines between circuits 28<sub>1</sub> and input 10<sub>3</sub> and output 10<sub>4</sub>. The request circuit 28<sub>1</sub> has therefore one input 30<sub>1</sub> connected to the third terminal of switch 14<sub>3</sub> and one output 32<sub>1</sub> connected to the third terminal of switch 14<sub>4</sub>.

In the operating mode represented on figure 1, the terminals 16<sub>2</sub> (16'<sub>2</sub>) and 16<sub>4</sub> (16'<sub>4</sub>) of switch 14<sub>1</sub> (14<sub>2</sub>), and the corresponding terminals of switches 14<sub>3</sub> and 14<sub>4</sub> are not used for transmitting data or signalling. However, these terminals, as shown on figure 2, are used for transporting data and signalling

when the spare board 12<sub>2</sub> becomes active and the board 12<sub>1</sub> becomes a spare board. Moreover, the terminals 16<sub>2</sub>, 16<sub>4</sub>, 16'<sub>2</sub> and 16'<sub>4</sub> are used for testing the connections to the board 12<sub>2</sub>. For this purpose, respective terminals 16<sub>4</sub> and 16'<sub>4</sub> of respective switches 14<sub>1</sub> and 14<sub>2</sub> are coupled to respective terminals 18<sub>2</sub> and 22<sub>2</sub>, of detection circuit 20<sub>2</sub> of terminating board 12<sub>2</sub>. Similarly, the fourth terminals of switches 14<sub>3</sub> and 14<sub>4</sub> are coupled to the terminals 30<sub>2</sub> and 32<sub>2</sub> of request circuit 28<sub>2</sub> of the terminal board 12<sub>2</sub>. Circuits 20<sub>2</sub> and 28<sub>2</sub> of the terminating board 12<sub>2</sub> have the same functions as circuits 20<sub>1</sub> and 28<sub>1</sub> of the terminating board 12<sub>1</sub>.

For the testing: of line 36<sub>1</sub> between terminal 16<sub>4</sub> of switch 14<sub>1</sub> and input terminal 18<sub>2</sub> of circuit 20<sub>2</sub>; of line 36<sub>2</sub> between terminal 16'<sub>4</sub> of switch 14<sub>2</sub> and input terminal 22<sub>2</sub> of circuit 20<sub>2</sub>; of line 36<sub>3</sub>, between the fourth terminal of switch 14<sub>3</sub> and terminal 30<sub>2</sub> of circuit 28<sub>2</sub>; and of line 36<sub>4</sub>, between the fourth terminal of switch 14<sub>4</sub> and input terminal 32<sub>2</sub> of circuit 28<sub>2</sub>, it is necessary that lines 36<sub>1</sub> and 36<sub>2</sub> are inside a closed loop and that lines 36<sub>3</sub> and 36<sub>4</sub> are also in a closed loop. For this purpose, terminal 16'<sub>2</sub> of switch 14<sub>2</sub> is coupled to terminal 16<sub>2</sub> of switch 14<sub>1</sub> and, in the same way, the second terminal of switch 14<sub>4</sub> is coupled to the second terminal of switch 14<sub>3</sub>, as can be observed from Fig. 2.

Therefore, the testing of the continuity of lines 36<sub>1</sub> and 36<sub>2</sub> is realized from detection circuit 20<sub>2</sub> of spare terminating board 12<sub>2</sub> and the testing of continuity of lines 36<sub>3</sub> and 36<sub>4</sub> is realized by request circuit 28<sub>2</sub> of the spare terminating board 12<sub>2</sub>.

In figure 1 and figure 2, the lines which are used for transmitting data and signalling are represented with black thick full lines and the lines which are tested, and not used for transporting data or signalling, are represented with thick dotted lines.

The 2x2 switches 14<sub>1</sub> and 14<sub>2</sub>, which, in an embodiment where W and P present optical fibres consist of optical switches, are installed on a board 40<sub>1</sub>. In the same way, the optical switches 14<sub>3</sub> and 14<sub>4</sub> are installed on a common board 40<sub>2</sub>. The boards 40<sub>1</sub> and 40<sub>2</sub> are installed on a panel 42 called here an "applique" panel. The active connections or couplings 38<sub>1</sub>, 38<sub>2</sub>, 38<sub>3</sub> and 38<sub>4</sub> to the board 12<sub>1</sub> and the reserved connections 36<sub>1</sub> to 36<sub>4</sub> are realized on a panel 44 called here a "back panel". The terminating boards 12<sub>1</sub>, 12<sub>2</sub> are installed on a "terminating panel" 46.

With this structure, each applique board 40<sub>1</sub>, 40<sub>2</sub> can be replaced easily. In the same way, each terminating board 12<sub>1</sub>, 12<sub>2</sub> can be replaced easily.

The exchanges of functions between boards  $40_1$  and  $40_2$ , and between boards  $12_1$  and  $12_2$  are done automatically. More particularly, when a fault is detected by controller  $26_1$  on the active board  $12_1$ , the controller  $26_1$  of the board sends a command signal to a priority logic circuit 41 between boards  $40_1$  and  $40_2$  in order to modify (switch over) the connections or couplings of the switches  $14_1$ ,  $14_2$  and  $14_3$ ,  $14_4$ . With this modification of the connections, which is represented on figure 2, the terminating board  $12_2$ , which was previously a spare board, becomes an active board and, reciprocally, the terminating board  $12_1$ , which was previously active, becomes a spare board. With these new connections or couplings, the data and the signalling are transmitted by the board  $12_2$ , and the board  $12_1$  is used to check the connections  $38_1$  to  $38_4$  which, on figure 2, are represented with thick dotted lines, the connections  $36_1$  to  $36_4$  being represented with black thick lines on this figure 2.

Preferably, the automatic protection switching, which replaces automatically a defective working link by a protecting link, is performed only on the terminating board  $12_1$  or  $12_2$  by means of circuits  $28_1$  and  $26_1$ , together constituting the first control means. The detection of defects is performed by detection circuit  $20_1$ , and the request for switching over from working link to protecting link is performed with the first control means, constituting of  $28_1$  and  $26_1$ , all being positioned on the same board. Consequently, the time for controlling the switch over can be minimized due to the fact that there is no delay to send the necessary control signals since these circuits are all on the same board and are not interfacing with other processors. This decentralised approach further adds to the speed.

When a new terminating board  $12_1$  will replace a previously defective board, while board  $12_2$  has already taken over, the connections  $38_1$ ,  $38_2$ ,  $38_3$  and  $38_4$ , and the circuits  $20_1$  and  $28_1$  of this new board  $12_1$  are used to check the correct operation of this new board. This checking operation may be performed in a minimized time due to the implementation of the checking circuit on the terminating board  $12_1$  itself, as is shown in figure 2.

The minimization of the replacement time and of the checking time is, of course, favorable to the minimization of data losses.

The exchange according to the invention may be used either with 1:1 or with 1+1 operation. As known, a 1:1 operation is such that the data are transmitted on the working link only and not on the protecting link. In the 1+1



operation, the data are transmitted on both links and, on the reception side, the data which are received with the best quality are selected.

In case of automatic protection switching, part of the functions of circuits 20<sub>1</sub> and 28<sub>1</sub> are exchanged and a switch 25<sub>1</sub> connects the data transmission circuit 24<sub>1</sub> from circuit 20<sub>1</sub> to circuit 28<sub>1</sub>.

The example which has been described with figure 1 and figure 2 is the simplest example of embodiment of the invention with one protection link for one working link and one spare board for one active terminating board. More generally, it is possible to select, at will, the number of protecting links and the number of working links; the number of active and spare terminating boards may also be selected at will and the protection ratios of the links and of the terminating boards may be chosen independently from each other.

In the embodiment represented on figure 3, on the applique board 42 two working links and two protecting links are provided. In other words, to each working link is associated a protecting link. The forward working lines W<sub>1</sub>, W<sub>2</sub> are connected to inputs 50<sub>1</sub> and 50<sub>2</sub>, and the corresponding forward protecting lines P<sub>1</sub>, P<sub>2</sub> are connected to inputs 50<sub>3</sub> and 50<sub>4</sub>. The return working lines W'<sub>1</sub>, W'<sub>2</sub> are connected to outputs 50<sub>5</sub> and 50<sub>6</sub>, and the corresponding return protecting lines P'<sub>1</sub>, P'<sub>2</sub> are connected to outputs 50<sub>7</sub> and 50<sub>8</sub>.

The terminating panel 46 is provided with an active terminating board 52 and an identical spare terminating board 54.

Each terminating board 52, 54 is provided with a number of circuits 20, 28 equal to the number of working and protecting links. More precisely, the active terminating board 52 is provided with a first data or detection circuit 20 for the working link (W<sub>1</sub>, W'<sub>1</sub>), a first request circuit 28 for the protecting link (P<sub>1</sub>, P'<sub>1</sub>), a second data circuit 20' for the second working link (W<sub>2</sub>, W'<sub>2</sub>), and a second request circuit 28' for the connection and protection of the second protecting link (P<sub>2</sub>, P'<sub>2</sub>).

The 2x2 switches 14'<sub>i</sub> of the applique panel 42 have their terminals connected in a similar way as terminals 16<sub>1</sub>, 16<sub>2</sub>, 16<sub>3</sub> and 16<sub>4</sub> in figure 1 and figure 2, more particularly the second terminal 16''<sub>2</sub> of the 2x2 switch 14'<sub>1</sub> is connected to the corresponding terminal of the switch 14'<sub>5</sub> on the return line W'<sub>1</sub>.

For the rest, the operation of the exchange represented on figure 3 is the same as the operation of the exchange described with figure 1 and figure 2.

In the embodiment represented on figure 4, only one protecting link P" is provided for three working links W"<sub>1</sub>, W"<sub>2</sub> and W"<sub>3</sub>. On the terminating panel 46", one spare board is provided for one active board.

Therefore, on each terminating board 58, 60, the number of automatic protection circuits (APS) corresponding to circuits 20<sub>1</sub> (data or detection) and 28<sub>1</sub> (request) of figure 1 is four : one for each working link and one for the protecting link. These APS circuits have the references respectively 64, 66, 68 and 70. The circuits 64, 66 and 68 are data circuits (similar to circuit 20<sub>1</sub> of figure 1) and the circuit 70 is a request circuit (similar to circuit 28<sub>1</sub> of figure 1). In addition, a common processor, similar to 26<sub>1</sub> is also present on the termination board, although it is not represented in the figure in order not to overload it. To the data circuits 64, 66, 68 and 70 correspond a switch 72 having a similar function as switch 25<sub>1</sub> of figure 1, i.e. the switch 72 normally provides the transmission of the data through the circuits 64, 66 and 68 but when a working link is replaced by the protecting link P", the switch 72 transmits the data through the circuit 70 for the working link which has been replaced by the protecting link.

Due to the fact that there is only one protecting link for three working links, it is necessary to provide priority rules for the boards 58 and 60 in order to determine which working link must be protected when more than one working link is defective.

The connections between the 2x2 switches and between the applique panel and the terminating panel are similar to those described with figure 1 and figure 3.

Although on figure 4 the number of working links is three, it is clear that this number of working links may have any value, for instance up to seven as provided by the ITU standard n° G.783.

As already mentioned, it is not absolutely necessary that an automatic protection switching be provided. In other words, the number of protecting links may be zero. An example of such embodiment is represented on figure 5. In this embodiment, one spare terminating board 80 is provided for three active terminating boards 82, 84, 86.

Due to the absence of a protecting link, the connection between the 2x2 switches is slightly different from the connection represented on figure 1 to figure 4. More precisely, on the forward lines W"<sub>1</sub>, W"<sub>2</sub>, W"<sub>3</sub>, the fourth terminal 16"<sub>4</sub> of switch 14"<sub>1</sub> is coupled to the second terminal 16<sub>2</sub> of switch 14"<sub>2</sub> and the fourth terminal of said switch 14"<sub>2</sub> is coupled to the second terminal of switch

14'''<sub>3</sub>. In a similar way, the switches 14'''<sub>1r</sub>, 14'''<sub>2r</sub>, 14'''<sub>3r</sub> of the return line W'<sub>1</sub>, W'<sub>2</sub> and W'<sub>3</sub> are connected in series, i.e. in the second terminal of switch 14'''<sub>3r</sub> is connected to the fourth terminal of switch 14'''<sub>2r</sub>, and second terminal of switch 14'''<sub>2r</sub> is connected to the fourth terminal of switch 14'''<sub>1r</sub>. The second terminal of switch 14'''<sub>1r</sub> is connected to the second terminal 16'''<sub>2</sub> of switch 14'''<sub>1</sub>.

The third terminals of switches 14'''<sub>1</sub> and 14'''<sub>1r</sub> are connected to the input and output terminals of the terminating board 82. In the same way, the third terminals of switches 14'''<sub>2</sub> and 14'''<sub>2r</sub> are connected to the input and output terminals of terminating board 84 and the third terminals of switches 14'''<sub>3</sub> and 14'''<sub>3r</sub> are connected to the input and output terminals of terminating board 86. The input and output terminals of the spare terminating board 80 are connected to the fourth terminals of, respectively, the switches 14'''<sub>3</sub> and 14'''<sub>3r</sub>.

Figure 5a shows the operation of the device of figure 5 in case of failures of terminating boards 82 and 84.

In this case, the 2x2 switches 14'''<sub>2r</sub> and 14'''<sub>2</sub> are controlled in order that the link W'''<sub>2</sub>, W'''<sub>2r</sub> be coupled to the spare terminating board 80.

In spite of the failure of terminating board 82, the corresponding 2x2 switches 14'''<sub>1</sub> and 14'''<sub>1r</sub> remain in their previous position. In other words, in this case, the second defective terminating board is not immediately automatically replaced because of the lack of extra-spare boards. In this situation, the control circuits are such that they establish a priority table to select the link which will be protected in case of failure of a number of active boards which is greater than the number of spare board (s).

Reference will now be made to figure 6 which represents an exchange according to the invention wherein one protecting link is provided for three working links and one spare terminating board is provided for three active terminating boards.

In order to simplify the representation, the forward and return lines of each link have been represented by a single line. Consequently, the pair of 2x2 switches which are associated, respectively, to the forward line and the return line have been represented by a single block 90<sub>i</sub>. For instance, the block 90<sub>1</sub> of figure 6 which is associated to the end of the link W<sub>10</sub> comprises two 2x2 switches which are in fact connected like the switches 14'''<sub>1</sub> and 14'''<sub>1r</sub> represented on figure 5.

This exchange comprises, on the applique panel 92, three identical sets or boards 94<sub>1</sub>, 94<sub>2</sub> and 94<sub>3</sub> of equipment each having pairs of 2x2 switches 90<sub>i</sub>

and the corresponding control circuits for the protection of the equipment on the terminating panel 96.

The board 94<sub>1</sub> is coupled to three working links W<sub>10</sub>, W<sub>20</sub>, W<sub>30</sub> and one protecting link P<sub>10</sub> and includes four pairs of 2x2 switches, respectively, 90<sub>1</sub>, 90<sub>2</sub>, 90<sub>3</sub> and 90<sub>4</sub>, i.e. eight 2x2 optical switches. Similarly, the board 94<sub>2</sub> is coupled to three working links W'<sub>10</sub>, W'<sub>20</sub>, W'<sub>30</sub> and one protecting link P'<sub>10</sub> and the board 94<sub>3</sub> is coupled to links W''<sub>10</sub>, W''<sub>20</sub>, W''<sub>30</sub> and P''<sub>10</sub>.

On the terminating panel 96, four terminating boards are provided, respectively, 98<sub>1</sub>, 98<sub>2</sub>, 98<sub>3</sub> and 98<sub>4</sub>, the boards 98<sub>1</sub>, 98<sub>2</sub> and 98<sub>3</sub> being active boards and the board 98<sub>4</sub> being a spare board.

Each of these terminating boards comprises automatic protection switching circuits like those of reference 20<sub>1</sub> and 28<sub>1</sub> and 26<sub>1</sub> as described with figure 1. The automatic protection switching circuits 100<sub>1</sub>, 100<sub>2</sub>, 100<sub>3</sub> and 100<sub>4</sub> are associated with the links, respectively, W<sub>10</sub>, W<sub>20</sub>, W<sub>30</sub> and P<sub>10</sub>.

As the terminating panel 96 comprises only one spare board 98<sub>4</sub> for protecting the three sets of working links W<sub>10</sub>, W<sub>20</sub>, W<sub>30</sub>, it is necessary to couple in series the switches of the boards 94<sub>1</sub>, 94<sub>2</sub> and 94<sub>3</sub>. More precisely, the switches 90<sub>1</sub> of board 94<sub>1</sub> are coupled in series with switches 90<sub>1</sub> of the two other boards 94<sub>2</sub> and 94<sub>3</sub> in order that all these sets of switches 90<sub>1</sub> be coupled to the protection circuits 100<sub>i</sub> of the spare board 98<sub>4</sub>.

The series connection or coupling is similar to the one described with figure 5.

The operation of this exchange represented on figure 6 is similar to the operation of the exchanges described with figure 4 and figure 5.

It is to be noted that, like for the embodiment of figure 5, it is necessary to provide priority rules for the protection of the sets of links associated to boards 94<sub>1</sub>, 94<sub>2</sub> and 94<sub>3</sub>, because there is only one spare board 98<sub>4</sub> for the three active boards 98<sub>1</sub>, 98<sub>2</sub> and 98<sub>3</sub> and in case of failure of more than one active board, the priority order must automatically determine which of the link sets will be selected for protection.

Although in the embodiment described with figure 6, one protecting link is provided for N working links and one spare board is provided for the same number N of active boards, it is possible to select independently the number n of working links which will be protected by one protecting link and the number m of active boards which will be protected by one spare board.

Figure 7 shows the general configuration of an exchange wherein  $p$  applique boards  $92_1, \dots, 92_p$  are provided. On each applique board  $92_i$ , are coupled  $m$  sets of  $n$  links and to these  $m$  sets of  $n$  links are associated  $m$  active boards  $98_1, \dots, 98_m$  and one spare board  $98_{m+1}$ .

- 5        The number of  $2 \times 2$  switches of the  $p$  applique panels may be easily calculated: to each link, corresponds two  $2 \times 2$  optical switches; therefore, the total number of switches is  $2nxm \times p$ .

- 10        According to the present state of the art, the maximum value of  $n$  may be 8, the maximum value of  $m$  may be 7 and the maximum value of  $p$  may be 3. Of course, these maximum values are just given as an example.

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